A PROJECT REPORT

On

Regenerating Energy Using Bicycle with Flywheel

Submitted by

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CERTIFICATE

This is to certify that the investigation presented in this project report like ideas, designs and experimental work, results, analyses and conclusions has been carried out by me. I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically indicated and acknowledged.

Ram Kishor Singh

ACKNOWLEDGEMENT

First and foremost, I would like to express immense gratitude to my *Sir, Ashish Tuli*. It has been a great learning experience working with him and a lot of credit for my achievements and accomplishments goes to him. His constant support and guidance have always motivated me to work and aided me to channelize my energy in the correct path. On a special note, I would like to acknowledge the affection, support and moral encouragement provided by my father *Mr. Shatrughan Singh* and mother *Mrs. Anusuiya Devi*. I am always thankful for their prayers and support and for listening to all my issues during my tough phase. Their prayers helped me to move forward in life.

ABSTRACT

During braking, a lot of energy is wasted as heat due to friction. If this energy can be stored and used again, it can reduce fuel consumption up to 20%. Cost of running is reduced significantly cost of running is reduced significantly. Lower emission of exhaust gases reduces pollution and Global Warming. The Mechanical Braking results in wear and tear of the brake linings & tires. Regenerative braking avoids such problems to an extent.

A decreased fuel consumption is very much important since the fuel reserves of nature are declining rapidly.

Energy recovery includes any technique or method of minimizing the input of energy to an overall system by the exchange of energy from one sub system of the overall system with another. The energy can be in any form in either subsystem, but most energy recovery systems exchange thermal energy in either sensible or latent form.

INDEX

LIST OF FIGURES

LIST OF TABLES

Chapter 1

Introduction to Regeneration

A kinetic energy recovery system (often known simply as KERS) is an automotive system for recovering a moving vehicle's kinetic energy under braking. The recovered energy is stored in a reservoir (for example a flywheel or high voltage batteries) for later use under acceleration. Examples include complex high end systems used in Formula One racing and simple, easily manufactured and integrated differential based systems such as the Cambridge Passenger Commercial Vehicle Kinetic Energy Recovery System (CPC KERS).

The CPC KERS is similar as it also forms part of the driveline assembly. However, the whole mechanism including the flywheel sits entirely in the vehicle's hub (looking like a drum brake). In the CPC KERS, a differential replaces the CVT and transfers torque between the flywheel, drive wheel and road wheel.

1.1 Principle

A common utilization of this principle is in systems which have an exhaust stream or waste stream which is transferred from the system to its surroundings. Some of the energy in that flow of material (often gaseous or liquid) may be transferred to the make up or input material flow. This input mass flow often comes from the system's surroundings, which, being at ambient conditions, are at a lower temperature than the waste stream. This temperature differential allows heat transfer and thus energy transfer, or in this case, recovery. Thermal energy is often recovered from liquid or gaseous waste streams to fresh make up air and water intakes in buildings, such as for the HVAC systems, or process systems.

1.2 Purpose of energy recovery

During braking, a lot of energy is wasted as heat due to friction. If this energy can be stored and used again, it can reduce fuel consumption up to 20%. Cost of running is reduced significantly cost of running is reduced significantly. Lower emission of exhaust gases reduces pollution and Global Warming. The Mechanical Braking results in wear and tear of the brake linings & tyres. Regenerative braking avoids such problems to an extent.

A decreased fuel consumption is very much important since the fuel reserves of nature are declining rapidly.

Energy recovery includes any technique or method of minimizing the input of energy to an overall system by the exchange of energy from one sub system of the overall system with another. The energy can be in any form in either subsystem, but most energy recovery systems exchange thermal energy in either sensible or latent form.

In some circumstances the use of an enabling technology, either diurnal thermal energy storage or seasonal thermal energy storage (STES, which allows heat or cold storage between opposing seasons), is necessary to make energy recovery practicable. One example is waste heat from air conditioning machinery stored in a buffer tank to aid in night time heating. Another is an STES application at a foundry in Sweden. Waste heat is recovered and stored in a large mass of native bedrock which is penetrated by a cluster of 140 heat exchanger equipped boreholes (155mm diameter) that are 150m deep. This store is used for heating an adjacent factory as needed, even months later.

An example of using STES to recover and utilize natural heat that otherwise would be wasted is the Drake Landing Solar Community in Alberta, Canada. The community uses a cluster of boreholes in bedrock for inter seasonal heat storage, and this enables obtaining 97 percent of the year round space heating from solar thermal collectors on the garage roofs. Another STES application is recovering the cold of winter by circulating water through a dry cooling tower, and using that to chill a deep aquifer or borehole cluster. The chill is later recovered from the storage for summer air conditioning. With a coefficient of performance (COP) of 20 to 40, this method of cooling can be ten times more efficient than conventional air conditioning.

Chapter 2

Flywheel

2.1 Introduction

Energy storage plays a big part in today's society, where almost everything we use in our everyday life requires energy to work. If this energy cannot be directly supplied to where it is needed, for from example the electrical grid, it is often instead taken from some kind of local energy storage. Today this local energy storage usually consists or either fuels such as wood and gasoline, or different kinds of batteries. The flywheel is another type of energy storage device that stores its energy as kinetic energy, or simply put in the rotational motion of the flywheel. Most flywheels are quite poor energy storage devices on their own, at least when concerning long term energy storage.

However, if designed correctly a flywheel's main strength lies in its ability to supply or absorb short, high energy, bursts or in other words it is good at absorbing or delivering high amounts of power for short amounts of time. As such it is often implemented alongside other energy storages in order to complement them where a need of instant high power may arise. This can for example be as balancing for the power grid or for short term backup power in for example hospitals, where a power shortage would be devastating.

This in order to allow for the use of less powerful batteries as the main energy storage in the vehicle and relying on the flywheel when high power is needed, such as when the vehicle tries to accelerate. Furthermore, the aim is also to absorb and store the energy released when the vehicle breaks by the use of regenerative breaking. The concept is by no means new and numerous research teams over the world have developed similar devices over the years.

However, very few have reached commercial successes. Usually due to economical limitations, the systems are simply too expensive for what they deliver. Some of the more successful projects include the work of K Takahashi, S Kitade, H Morita who built an experimental rotor. Containing a complete flywheel system designed for use in a Formula 1 car, storing 22Wh/kg of energy in their rotor. Energy storage is becoming increasingly important with the advent of individual electronic devices and the rising need to accommodate a greater population, which relies on these devices. This author proposes the use of flywheel energy storage in conjunction with differential absorption as a method for generating clean long lasting energy.

A flywheel is a rotating mechanical device that is used to store rotational energy. Flywheels have a significant moment of inertia and thus resist changes in rotational speed. The amount of energy stored in a flywheel is proportional to the square of its rotational speed. Energy is transferred to a flywheel by applying torque to it, thereby increasing its rotational speed, and hence its stored energy. Conversely, a flywheel releases stored energy by applying torque to a mechanical load, thereby decreasing its rotational speed. Common uses of a flywheel include.

Providing continuous energy when the energy source is discontinuous. For example, flywheels are used in reciprocating engines because the energy source, torque from the engine, is intermittent. Delivering energy at rates beyond the ability of a continuous energy source. This is achieved by collecting energy in the flywheel over time and then releasing the energy quickly, at rates that exceed the abilities of the energy source.

Controlling the orientation of a mechanical system. In such applications, the angular momentum of a flywheel is purposely transferred to a load when energy is transferred to or from the flywheel.

Flywheels are typically made of steel and rotate on conventional bearings these are generally limited to a revolution rate of a few thousand RPM. Some modern flywheels are made of carbon fiber materials and employ magnetic bearings, enabling them to revolve at speeds up to 60,000 RPM.

Carbon composite flywheel batteries have recently been manufactured and are proving to be viable in real world tests on mainstream cars. Additionally, they are more eco friendly, as it is not necessary to take special measures in the disposal of them. Without entering into a large discussion on flywheel design and technical considerations or differential absorption a small amount of background information shall be presented to familiarize the reader with the general theory behind the concept.

The flywheel energy storage system is a unique device that can meet the current and future requirements of energy storage for small electronic devices. The flywheel energy storage system is superior to current devices as well as the recent influx of foreseeable devices such as fuel cells. The flywheel energy storage system is environmentally friendly and poses no health risks to biological organisms upon disposal or during operation. The flywheel energy storage system is user friendly being turn able to a wide variety of powers and situations and the simplicity of the device reduces the malfunction and breakage during operation and production. Apart from operational attributes one of the greatest achievements of the flywheel energy storage system is its adaptive nature to meet the needs of individuals across many disciplines and situations. From remote secluded areas on the globe to populated cities, the flywheel energy storage system provides long lasting energy when needed.

2.2 History

In early 2005, an article on the subject of flywheels as energy storages was published from Uppsala University. The ideas presented in this article were to become the starting grounds for a new flywheel research group in Uppsala. Under the years following 2005 the group's main focus became the development of a complete driveline for an electrical vehicle, a driveline in which a central flywheel was used as the main power source for the electrical motors.

The flywheel was then to be charged by a separate battery powered circuit. The project is now in its final stages and as such a first full scale prototype flywheel is being constructed. A vital part of the flywheel concept developed in Uppsala University is the use of composite materials as the main energy storage material. With the overall design decided and much of the electrical design already done the focus of this thesis will be the design of the composite materials for the full scale flywheel prototype.

The principle of the flywheel is found in the Neolithic spindle and the potter's wheel. The flywheel as a general mechanical device for equalizing the speed of rotation is, according to the American medievalist Lynn. James Watt contributed to the development of the flywheel in the steam engine, and his contemporary James Pickard used a flywheel combined with a crank to transform reciprocating into rotary motion.

2.3 Flywheel functions, need and operations

Flywheels are often used to provide continuous energy in systems where the energy source is not continuous. In such cases, the flywheel stores energy when torque is applied by the energy source, and it releases stored energy when the energy source is not applying torque to it. For example, a flywheel is used to maintain constant angular velocity of the crankshaft in a reciprocating engine. In this case, the flywheel which is mounted on the crankshaft stores energy when torque is exerted on it by a firing piston, and it releases energy to its mechanical loads when no piston is exerting torque on it. Other examples of this are friction motors, which use flywheel energy to power devices such as toy cars.

A flywheel may also be used to supply intermittent pulses of energy at transfer rates that exceed the abilities of its energy source, or when such pulses would disrupt the energy supply (e.g., public electric network). This is achieved by accumulating stored energy in the flywheel over a period of time, at a rate that is compatible with the energy source, and then releasing that energy at a much higher rate over a relatively short time. For example, flywheels are used in riveting machines to store energy from the motor and release it during the riveting operation.

The phenomenon of precession has to be considered when using flywheels in vehicles. A rotating flywheel responds to any momentum that tends to change the direction of its axis of rotation by a resulting precession rotation. A vehicle with a vertical axis flywheel would experience a lateral momentum when passing the top of a hill or the bottom of a valley (roll momentum in response to a pitch change). Two counter rotating flywheels may be needed to eliminate this effect. This effect is leveraged in reaction wheels, a type of flywheel employed in satellites in which the flywheel is used to orient the satellite's instruments without thrusters rockets.

The main function of a fly wheel is to smoothen out variations in the speed of a shaft caused by torque fluctuations. If the source of the driving torque or load torque is fluctuating in nature, then a flywheel is usually called for. Many machines have load patterns that cause the torque time function to vary over the cycle. Internal combustion engines with one or two cylinders are a typical example. Piston compressors, punch presses, rock crushers etc. are the other systems that have flywheel. Flywheel absorbs mechanical energy by increasing its angular velocity and delivers the stored energy by decreasing its velocity.

2.4 Theory

Some basic material theory is required to understand the concepts presented. The first part presents a quick briefing as to why flywheels are interesting as energy storage and after that follows some composite material theory. Finally, the most important part how stresses in composite cylinders can be calculated.

Flywheels are generally used for kinetic energy storage and have been around since the early times of man. Every object rotating around an axis stores some amount of kinetic energy and could in theory be called a flywheel. But the word flywheel is usually used for constructions whose main purpose is the storage of kinetic energy through rotation. This has led to the convention that the term flywheel describes a rotating, cylindrical object, usually of considerable mass, whose main purpose is to store energy or to increase the moment of inertia of a given system.

The kinetic energy stored in a solid disk or cylinder shaped flywheel is proportional to its speed and diameter according to equation

$$E_k = I \; 2 \qquad (2.1)$$

where

E_k is the kinetic energy,

I is the moment of inertia around its center of mass, and   is the angular

velocity

Upon examination of the above equation it is obvious that two situations are possible. Build a colossal flywheel that spins slow enough to not throw it apart or build a small Herculean flywheel that can be spun extremely fast. It is easy and rather amusing to envision large wheels attached to buildings being spun by wind and water with birds changing their quarter or compact disc contained in near 100% vacuum chambers being spun at thousands or revolutions per minute on magnetic bearings. While several problems are associated with either option, the latter shall be examined.

The easiest method of increasing the kinetic energy in the flywheel is to increase the angular velocity. Due to the increase of radial and hoop stresses (depending on design) associated with increasing angular velocity lighter stronger monofilament materials are desired.

For the design the following parameters have been considered

Outer diameter (Do) = 220 mm

Inner diameter (D_i) = 110 mm
Weight of the flywheel (W) = 8 Kg = 0.07845 kN

Revolution = 2 rps

2.4.1 Design of flywheel considering as normal disc

For a circular disc with a centre hole

We have the equation for moment of inertia (I)

$$I = \_\_ \; (D_o^4 – Di^4) \qquad (2.2)$$

$$= \quad (220^4 \quad 110^4) = \mathbf{107.806 \times 10^6 \, mm^4}$$

Area (A) of the disc is given by

$$A = (D_o^2 – Di^2) \qquad (2.3)$$

$= (220^2 \quad 110^2) =$ **28.50×10^3 mm²**

Radius of gyration (K)

K = (2.4)

$= \{ (107.806 \times 10^6) / (28.50 \times 10^3) \} =$ **61.50**

2.4.2 Design of flywheel

The radius of gyration of flywheel (k)

$k^2 = \underline{\quad}$ (2.5)

$= \underline{\quad} = 6050$

k = **77.78 mm**

Velocity (v) $= D_o N$ (2.6)

$= \times 220 \times 10^3 \times 2 = 1.38$ m / sec

For kinetic energy $K_E = m^2 = I^2 = \underline{\quad}$ (2.7)

= = **7.614 Joules**

Coefficient of fluctuation of rotation C_f

Driven Machine	Type of drive	C_f
AC generators	Direct coupled	0.01
AC generators	Belt	0.0167
DC generators	Direct coupled	0.0143
DC generators	Belt	0.029

Spinning machinery	Belt	0.02 0.015
Compressor, pumps	Gears	0.02
Paper, textile, flour mills	Belt	0.025 0.02
Shears and pump	Flexible coupling	0.05 0.04
Crushers, hammers, punch press, low loads	Belt	0.2
Concrete mixture	Belt	0.143 0.1

Table 2.1 Coefficient of fluctuation of rotation C_f

Considering the value of $C_f = 0.2$ (Low loads from the above table) The coefficient

of steadiness (m)

m = (2.8)

= ___ = **5**

The change in kinetic energy or excess energy (E)

$E = (W v^2 C_f) / g$ (2.9) = ($0.07845 \times 10^3 \times 1.38^2 \times 0.2$) / 9.81 = **3.048 Joule**

2.5 Design Approach

The amount of energy required for the desired degree of smoothening must be found and the (mass) moment of inertia needed to absorb that energy determined. Then flywheel geometry must be defined that caters the required moment of inertia in a reasonably sized package and is safe against failure at the designed speeds of operation.

2.6 Limitations

The following limitations were applied to the thesis in order to simplify the calculations and to maintain the number of design parameters on a reasonable level.

I. All composite calculations are based on the assumption of zero axial force.
Additionally only carbon and glass fibres are investigated.

II. Most machine dimensions were set at the start of this thesis.

III. All equations and derivations are based on an assumption of zero shear force and torque in all material directions, meaning that they only hold true as long as the system is in stationary operation.

IV. In all equations an assumption of a system in thermal equilibrium is made, meaning that no temperature change over time is present.

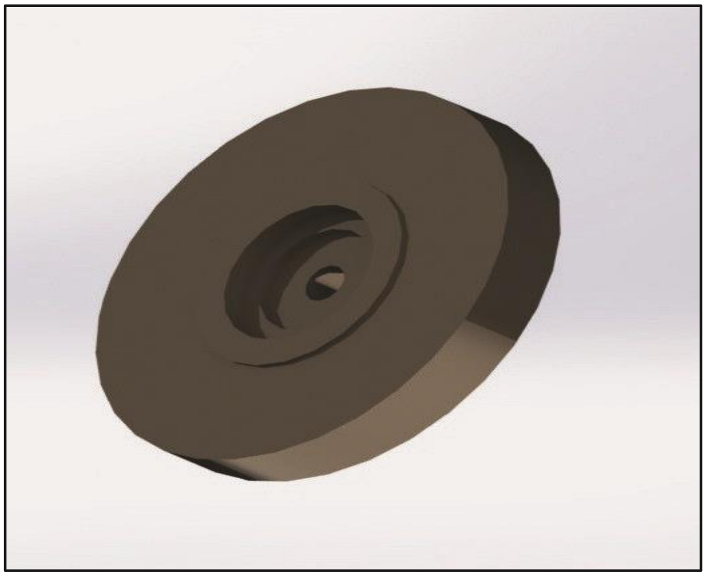

Figure 2.1 Design of flywheel

Chapter 3

Clutch

3.1 Introduction

Clutch connects, disconnects drive to transmission. Most outdoor power equipment use either belt tensioning clutch or friction disc clutch (also called pressure plate clutch). Larger achiness may use friction disk plus shaft drive. If machine uses hydrostatic transmission, won't have separate clutch. Clutch function handled by hydrostatic assembly. Clutch is device that connects and disconnects drive from transmission. Riding mower or tractor usually contains either belt tensioning clutch or friction disc clutch (also called pressure plate clutch). Larger garden tractor may use friction disc clutch in combination with shaft drive. If tractor contains hydrostatic transmission, won't have separate clutch.

Typical belt tensioning clutch uses spring loaded idler pulleys to control belts. When clutch pedal depressed, idler pulley retracts from transmission belt and disengages transmission. When clutch pedal released, idler pulley springs back into position, pushes on transmission belt to engage transmission. Friction disc clutch usually located directly between engine and transmission. In this type clutch, one disc driven by engine, the other disc connected to output shaft. Disc driven by engine called drive disc, disc connected to output shaft driven disc.

Friction materials or lugs placed on surface drive disc enable drive disc to engage driven disc. As long as two discs not touching, drive disc can spin freely without affecting driven disc. If discs pressed together, spinning drive disc will engage driven disc, two discs will spin together. Spring loaded mechanism connected to clutch pedal used to pull discs together or apart. When clutch pedal on mower released, discs pressed together and clutch engages. When clutch pedal pressed down, discs move away from each other and clutch disengages.

Two major types disc or plate clutches, dry clutch and wet clutch. Dry clutch similar to automotive clutch, usually seen only on larger tractor. Six main components clutch assembly are engine flywheel, clutch disc, pressure plate and cover, clutch release bearing, and clutch release fork or release linkage.

In dry clutch, clutch disc mounted between engine's flywheel and pressure plate (more than one clutch plate may be used). Pressure plate fastened to engine flywheel.

Clutch side of flywheel machined to provide friction surface for clutch disc. Clutch disc covered with friction material on both sides. Clutch release bearing slides on transmission input shaft and is moved by clutch linkage. Linkage attached to clutch pedal. Clutch springs hold pressure against pressure plate and driven disc. When operator presses down clutch pedal, linkage releases spring tension and causes driven disc to disengage from engine, so power transfer is stopped. When operator releases clutch pedal, spring pushes pressure plate against driven disc, power is reconnected from engine to transmission.

Wet clutch contains series discs splined to drum and pressure plates splined to a hub. Drum connected to input shaft, hub connected to output shaft. Both sides each disc covered with friction material. Disc and plates run in oil. When hydraulic pressure applied, disc and plates pressed together. Disc and plates rotate together, hub and drum rotate together, and power transferred from input shaft to output shaft.

In some units, plates and disc forced together mechanically. Important to remember basic difference between dry clutch and wet clutch. Dry clutch won't operate if contaminated with oil, discs will slip and prevent transmission from engaging. Wet clutch must have oil to run properly. Larger garden tractors may use electromagnetic clutches to drive mower decks and attachments. Electromagnetic clutch works same way as friction disc clutch. Instead using spring pressure to push discs together, electromagnetic clutch uses electromagnetism to pull and hold two steel discs together. Drive disc keyed to engine PTO shaft. Driven attached to a pulley, and belt from this pulley continues power drive. Electromagnetic clutch assemblies inexpensive and easily installed. Control mechanism consists of length electric wire and ON OFF switch.

3.2 Clutch mechanisms

Pulley system is way to transfer power. Clutch mechanism used to modify or change amount power being transferred by engaging or disengaging parts of power transfer system. If think about operation slack adjuster described earlier, can understand how clutch used in pulley system. If operator were to remove spring and use idler pulley in mechanism to modify amount power delivered, operator would be using slack adjuster's idler pulley as a clutch on the pulley system.

3.3 Types of clutches

The idler pulley clutch idler pulley that adjusts belt tension can be used as inexpensive clutch. Instead of spring, idler arm used to control pulley. This type clutch called an idler pulley clutch. With such clutch, operator can engage pulley to belt gradually, thus feathering the applied power. With idler arm, operator can control amount slipping that occurs as pulley engages belt. When troubleshooting, check to see that idler arm can move freely, and that bearings lubricated as specified.

Friction Clutch

Friction clutches are the most commonly used clutch mechanisms. They are used to transmit torque by using the surface friction between two faces of the clutch.

Dog Clutch

A dog clutch couples two rotating shafts or other rotating components not by friction, but by interference. Both the parts of the clutch are designed so that one pushes into the other, causing both to rotate at the same speed, so that they never slip.

Cone Cutch

Cone clutches are nothing, but frictional clutches with conical surfaces. The area of contact differs from normal frictional surfaces. The conical surface provides a taper, which means that while a given amount of actuating force brings the surfaces of the clutch into contact really slowly, the pressure on the mating surfaces increases rapidly.

Overrunning Clutch

Also known as the freewheel mechanisms, this type of clutch disengage the driveshaft from the driven shaft, when the driven shaft rotates faster than the driveshaft. An example of such a situation can be when a cyclist stops peddling and cruises. However, in case of automobiles going down the hill, you cannot take your feet off the gas pedal, as there is no free wheel system. If you do so, the whole engine system can be damaged.

Safety Clutch

Also known as the torque limiter, this device allows a rotating shaft to "slip" or disengage when higher than normal resistance is encountered on a machine. An example of a safety clutch is the one mounted on the driving shaft of a large grass mower. If a stone or something else is encountered by the grass mower, it stops immediately and does not hamper the blades.

Centrifugal clutch

Centrifugal and semi centrifugal clutches are employed where they need to engage only at some specific speeds. There is a rotating member on the driving shaft, which rises up as the speed of the shaft increases and engages the clutch, which then drives the driven shaft.

Hydraulic Clutch

In a hydraulic clutch system, the coupling is hydrodynamic and the shafts are not actually in contact. They work as an alternative to mechanical clutches. They are known to have common problems associated with hydraulic couplings, and are a bit unsteady in transmitting torque.

Electromagnetic Clutch

These clutches engage the theory of magnetism on to the clutch mechanisms. The ends of the driven and driving pieces are kept separate and they act as the pole pieces of a magnet. When a DC current is passed through the clutch system, the electromagnet activates and the clutch is engaged.

3.4 Principles

The main system of the friction clutch consists of pressure plate, clutch disc and flywheel as shown in figure. When the clutch starts to engage, slipping will occur between contact surfaces due to the difference in the velocities between them (slipping period). After this period all contact part are rotating at the same velocity without slipping (full engagement period).

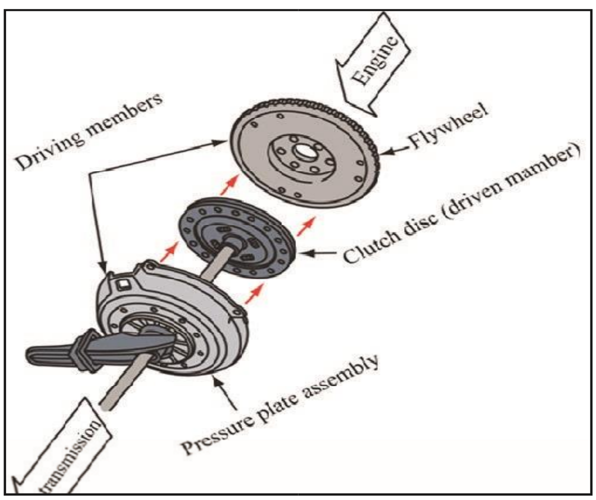

Figure 3.2 Transmission

Figure 3.3 Modelled clutch

Chapter 4

Cam

4.1 Introduction

A mechanical cam is a rotating or sliding piece in a mechanical linkage. It is used particularly in transforming rotary motion into linear motion. It is often part of a rotating wheel or shaft that strikes a lever at one or more points on its circular path. The cam can be a simple tooth, as is used to convey pulses of power to a steam hammer. Cams come in all shapes and sizes and are found in most branches of engineering. Indeed without them many of our everyday appliances would not work.

Simple cams form the basis of rotary cam timers which are used to control some household appliances, car engine would not work without the cams and many industrial machine tools rely upon them. In truth cams are ubiquitous. Take a pencil and a book to do an experiment as shown above. Make the book an inclined plane and use the pencil as a slider (use your hand as a guide). When you move the book smoothly upward, what happens to the pencil? It will be pushed up along the guide.

By this method, you have transformed one motion into another motion by a very simple device. This is the basic idea of a cam. By rotating the cams in the figure below, the bars will have either translational or oscillatory motion.

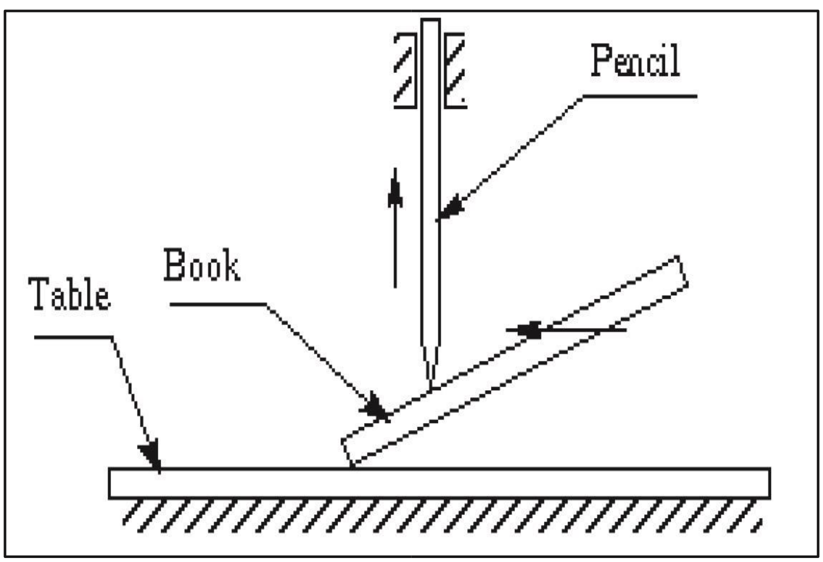

Figure 4.1 Basic principle of cam

The transformation of one of the simple motions, such as rotation, into any other motions is often conveniently accomplished by means of a cam mechanism. A cam mechanism usually consists of two moving elements, the cam and the follower, mounted on a fixed frame.

Cam devices are versatile, and almost any arbitrarily specified motion can be obtained. In some instances, they offer the simplest and most compact way to transform motions. A cam may be defined as a machine element having a curved outline or a curved groove, which, by its oscillation or rotation motion, gives a predetermined specified motion to another element called the follower .

The cam has a very important function in the operation of many classes of machines, especially those of the automatic type, such as printing presses, shoe machinery, textile machinery, gear cutting machines, and screw machines. In any class of machinery in which automatic control and accurate timing are paramount, the cam is an indispensable part of mechanism. The possible applications of cams are unlimited, and their shapes occur in great variety.

4.2 Classification of cam mechanisms

We can classify cam mechanisms by the modes of input/output motion, the configuration and arrangement of the follower, and the shape of the cam. We can also classify cams by the different types of motion events of the follower and by means of a great variety of the motion characteristics of the cam profile.

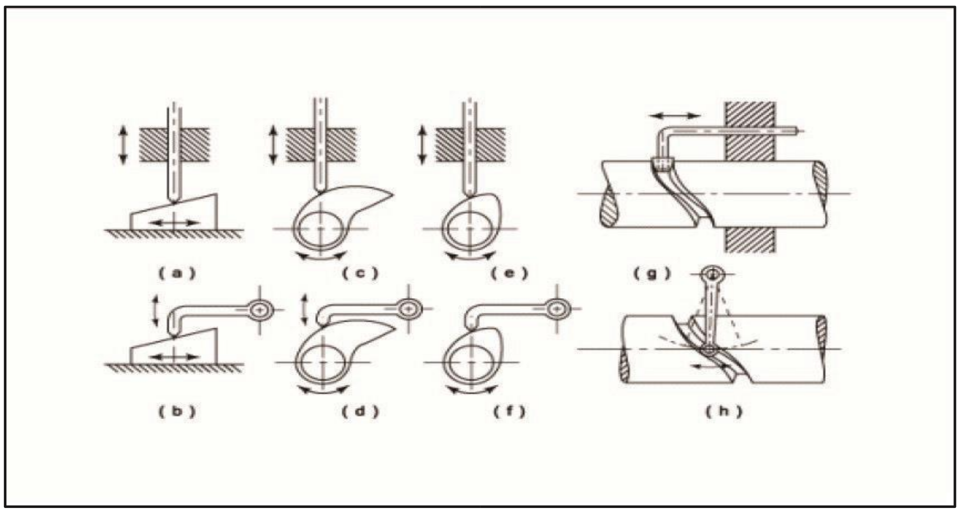

Figure 4.2 Different arrangement of cams

4.3 Cam design

The translational or rotational displacement of the follower is a function of the rotary angle of the cam. A designer can define the function according to the specific requirements in the design.

4.4 Cam profile design principle

The method termed inversion is commonly used in cam profile design. For example, in a disk cam with translating follower mechanism, the follower translates when the cam turns. This means that the relative motion between them is a combination of a relative turning motion and a relative translating motion. Without changing this feature of their relative motion, imagine that the cam remains fixed. Now the follower performs both the relative turning and translating motions. We have inverted the mechanism.

4.5 History

An early cam was built into Hellenistic water driven automata from the 3rd century BC. The camshaft was later described in Iraq (Mesopotamia) by Al Javari in 1206. He employed it as part of his automata, water raising machines, and water clocks such as the castle clock. The cam and camshaft later appeared in European mechanisms from at least the 14th century or possibly earlier.

4.7 Uses

In internal combustion engines with pistons, the camshaft is used to operate poppet valves. It then consists of a cylindrical rod running the length of the cylinder bank with a number of oblong lobes protruding from it, one for each valve. The cam lobes force the valves open by pressing on the valve, or on some intermediate mechanism as they rotate.

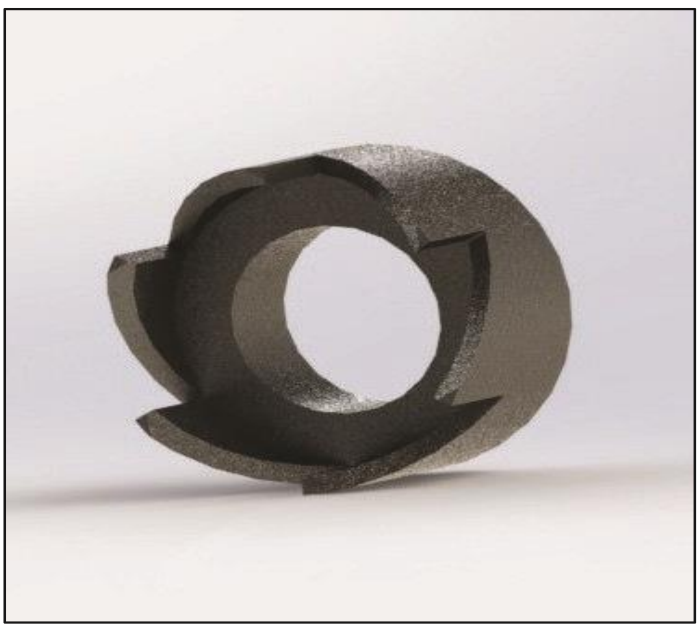

Figure 4.3 Modelled Cam

Chapter 5

Shafts

5.1 Introduction

Shafts are used to transmit power to other mechanical elements and are generally subjected to torsional and bending loads. One of the most common failure mechanisms in shafts is fatigue. Fatigue failures start at vulnerable points where metallurgical and structural defects exist that favour high localized stresses. Normally, the points of stress concentration in shafts are present in sharp changes of the cross sectional area or at the keyways. Additionally, when defects appear in these sensitive sites, the fatigue life is severely compromised.

Other failure analyses have been performed on shafts, especially related to the corners of the keyway, where the predominant causes of the onset of fatigue failure were due to low radius of keyway curvature inclusions, incorrect repair welding, brittle microstructures, and machining marks. All of these failures were present across the entire cross section of the shafts and started at the corners of the keyway. In this failure analysis, only one side of the keyway was completely fractured by fatigue, not the entire transversal section. Besides, this type of failure has been recurrent in this mechanical element for years

The shaft analyzed (replacement part) belongs to a bridge crane fractured after one year of operation. Fundamentally, the bridge crane system consists of an electric motor that transmits power to the shaft and this shaft transmits power to a reducer gearbox a representation of the system. The keyway connects the system’s brake. According to the material specification provided by the manufacturer, the material is an AISI 4340 steel normalized and tempered. A drive shaft, driveshaft, driving shaft, propeller shaft (prop shaft),it is a mechanical component for transmitting torque and rotation, usually used to connect other components of a drive train that cannot be connected directly because of distance or the need to allow for relative movement between them.

Drive shafts are carriers of torque they are subject to torsion and shear stress, equivalent to the difference between the input torque and the load. They must therefore be strong enough to bear the stress, whilst avoiding too much additional weight as that would in turn increase their inertia. To allow for variations in the alignment and distance between the driving and driven components, drive shafts frequently incorporate one or more universal joints, jaw couplings, or rag joints, and sometimes a splined joint or prismatic joint.

5.2 History

The term drive shaft first appeared during the mid 19th century. In Storer's 1861 patent reissue for a planning and matching machine, the term is used to refer to the belt driven shaft by which the machine is driven. The term is not used in his original patent. Another early use of the term occurs in the 1861 patent reissue for the Watkins and Bryson horse drawn mowing machine. Here, the term refers to the shaft transmitting power from the machine's wheels to the gear train that works the cutting mechanism. In the 1890s, the termbegan to be used in a manner closer to the modern sense. In 1891, for example, Battles referred to the shaft between the transmission and driving trucks of his Climax locomotive.

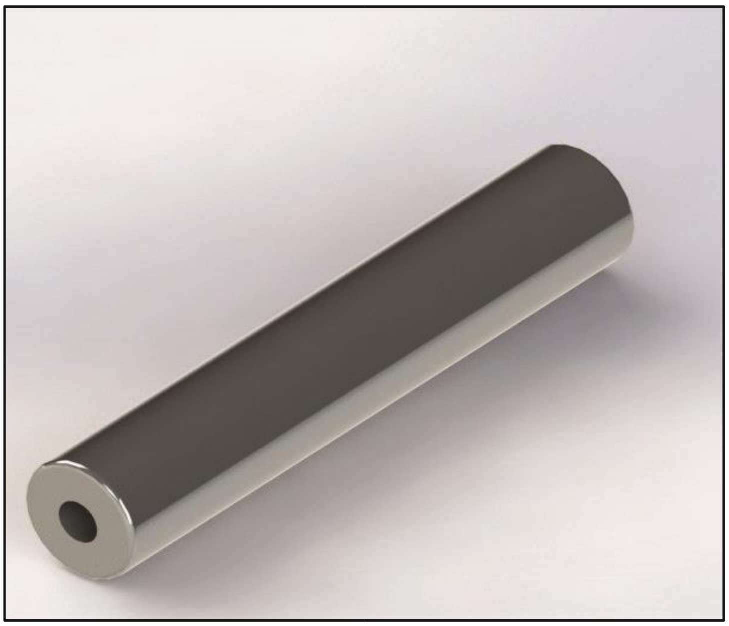

Figure 5.1 Modelled shaft

5.3 Advantages

1. Drive system is less likely to become jammed, a common problem with chain driven bicycles
2. The rider cannot become dirtied from chain grease or injured by "Chain bite" when clothing or a body part catches between an unguarded and a sprocket
3. Lower maintenance than a chain system when the drive shaft is enclosed in a tube
4. More consistent performance. Dynamic Bicycles claims that a drive shaft bicycle can deliver 94% efficiency, whereas a chain driven bike can deliver anywhere from 75 97% efficiency based on condition

5. Greater ground clearance lacking a derailleur or other low hanging machinery, the bicycle has nearly twice the ground clearance

5.4 Disadvantages

1. A drive shaft system weighs more than a chain system, usually 12 pounds heavier
2. Many of the advantages claimed by drive shaft's proponents can be achieved on a chain driven bicycle, such as covering the chain and gears
3. Use of lightweight gears with a high number of ratios is impossible, although hub gears can be used
4. Wheel removal can be complicated in some designs (as it is for some chain driven bicycles with hub gears).
5. A chain is made up of series of links with the links held together with steel pins. This arrangement makes a chain a strong, long lasting way of transmitting rotary motion from one gear wheel to another.

Chapter 6

Chain and sprocket

6.1 Introduction

Chain drive has one main advantage over a traditional gear train. Only two gear wheels and a chain are needed to transmit rotary motion over a distance. With a traditional gear train, many gears must be arranged meshing with the each other in order to transmit motion. When working out gear / velocity ratio and the rpm of chain driven gears it must be remembered that the chain is ignored. This means that you simply find out the teeth per gear wheel and the rpm and use the same method of calculating as you would with a normal meshing gear system.

A sprocket or sprocket wheel is a profiled wheel with teeth or cogs that mesh with a chain, track or other perforated or indented material. The name "sprocket" applies generally to any wheel upon which are radial projections that engage a chain passing over it. It is distinguished from a gear in that sprockets are never meshed together directly, and differs from a pulley in that sprockets have teeth and pulleys are smooth. The word "sprockets" may also be used to refer to the teeth on the wheel.

Sprockets are used in bicycles, motorcycles, cars, tracked vehicles, chain saws and other machinery to transmit rotary motion between two shafts where gears are unsuitable or to impart linear motion to a track, tape etc. Perhaps the most common form of sprocket may be found in the bicycle, in which the pedal shaft carries a large sprocket wheel, which drives a chain, which, in turn, drives a small sprocket on the axle of the rear wheel. Early automobiles were also largely driven by sprocket and chain mechanism, a practice largely copied from bicycles.

Sprockets are of various designs, a maximum of efficiency being claimed for each by its originator. Sprockets typically do not have a flange. Some sprockets used with timing belts have flanges to keep the timing belt centered. Sprockets and chains are also used for power transmission from one shaft to another where slippage is not admissible, sprocket chains being used instead of belts or ropes and sprocket wheels instead of pulleys. They can be run at high speed and some forms of chain are so constructed as to be noiseless even at high speed.

Figure 6.1 Modelled sprocket

In the case of bicycle chains, it is possible to modify the overall gear ratio of the chain drive by varying the diameter (and therefore, the tooth count) of the sprockets on each side of the chain. This is the basis of derailleur gears. A multi speed bicycle, by providing two or three different sized driving sprockets and up to 11 (as of 2014) different sized driven sprockets, allows up to 30 different gear ratios. The resulting lower gear ratios make the bike easier to pedal up hills while the higher gear ratios make the bike more powerful to pedal on flats and down hills. In a similar way, manually changing the sprockets on a motorcycle can change the characteristics of acceleration and top speed by modifying the final drive gear ratio. A sprocket is a toothed wheel upon which a chain rides. Contrary to popular opinion, a sprocket is not a gear

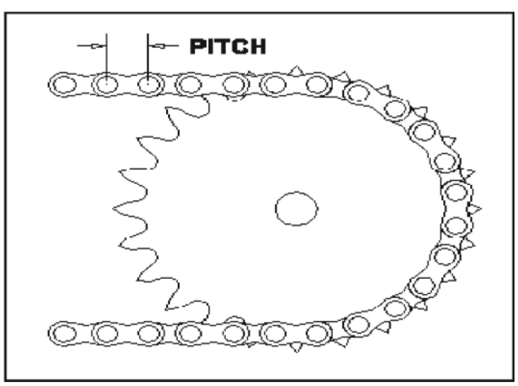

Figure 6.2 Pitch of chain

6.2 History

Obsolete chain designs previously used on bicycles included the block chain, the skip link chain, and the Simpson lever chain. Most modern bicycle chains used with a single chain ring and single rear sprocket are conventional industrial bushing chain. Until the 1980s, most derailleur chains were also bushing chains, but today, virtually all derailleur chains are of the bushing less design. Compared to a bushing chain, a bushing less chain is cheaper to make, is less likely to break under shifting load, promotes better lubricant flow inside the rollers, and creates more lateral flexibility for multi geared bicycles.

However, it also wears much faster and has slightly worse mechanical efficiency than a bushing chain. Before the safety bicycle, bicycles did not have chains and the pedals were typically attached directly to the drive wheel, thus limiting top speed by the diameter of the wheel and resulting in designs with front wheels as large as possible. Various linkage mechanisms were invented to raise the effective gear ratio, but with limited success.

Using chain drive allowed the mechanical advantage between the drive and driven sprockets to determine the maximum speed, thereby enabling manufacturers to reduce the size of the driving wheel for safety. It also allowed for the development of variable gearing, allowing cyclists to adjust their gearing to the difficulty of the terrain, on the fly. A bicycle chain can be very energy efficient one study reported efficiencies as high as 98.6%. A larger sprocket will give a more efficient drive, reducing the movement angle of the links. Higher chain tension was found to be more efficient "This is actually not in the direction you'd expect, based simply on friction.

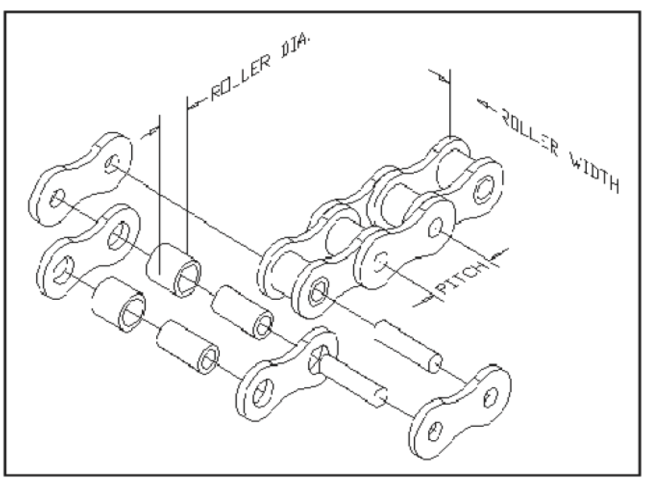

Figure 6.3 Chain construction

6.3 Chain construction

Chains have a surprising number of parts. The roller turns freely on the bushing, which is attached on each end to the inner plate. A pin passes through the bushing, and is attached at each end to the outer plate. Bicycle chains omit the bushing, instead using the circular ridge formed around the pin hole of the inner plate.

6.4 Chain dimensions

Chain types are identified by number i.e. a number 40 chain. The rightmost digit is 0 for chain of the standard dimensions 1 for lightweight chain and 5 for roller less bushing chain. The digits to the left indicate the pitch of the chain in eighths of an inch. For example, a number 40 chain would have a pitch of four eighths of an inch, or 1/2", and would be of the standard dimensions in width, roller diameter, etc.

The roller diameter is "nearest binary fraction" (32nd of an inch) to 5/8ths of the pitch pin diameter is half of roller diameter. The width of the chain, for "standard" (0 series) chain, is the nearest binary fraction to 5/8ths of the pitch for narrow chains (1 series) width is 41% of the pitch. Sprocket thickness is approximately 85 90% of the roller width. Plate thickness is 1/8th of the pitch, except "extra heavy" chain, which is designated by the suffix H, and is 1/32" thicker.

6.5 Centre distance

For optimum wear life, centre distance between two sprockets should normally be within the range 30 to 50 times the chain pitch. On drive proposals with centre distances below 30 pitches or greater than 2 metres, we would recommend that the drive details are discussed with our technical staff. The minimum centre distance is sometimes governed by the amount of chain lap on the driver sprocket, our normal recommendation in this circumstance being not less than six teeth in engagement with the chain.

The centre distance is also governed by the desirability of using a chain with an uneven number of pitches to avoid the use of a cranked link, a practice that is not recommended except in special circumstances.

For a drive in the horizontal plane, the shortest centre distance possible should be used consonant with recommended chain lap (maximum six teeth) on the driver sprocket.

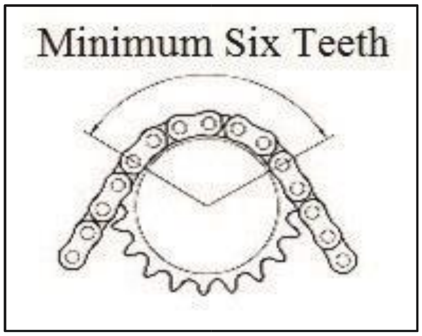

Figure 6.4 Centre distance

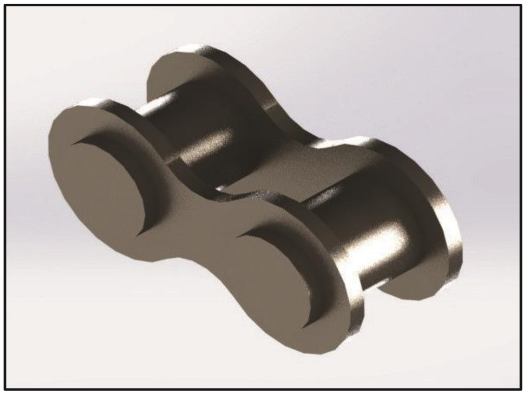

Figure 6.6 Chain segment B

6.6 Applications

Sprockets should be accurately aligned in a common vertical plane, with their axes parallel. Chain should be kept clean and well lubricated with a thin, light bodied oil that will penetrate the small clearances between pins and bushings.

Centre distance should not be less than 1.5 times the diameter of the larger sprocket, nor less than 30 times the chain pitch, and should not exceed 60 times the chain pitch. Centre distance should be adjustable one chain pitch is sufficient and failing this an idler sprocket should be used to adjust tension. A little slack is desirable, preferably on the bottom side of the drive.

The chain should wrap at least 120° around the drive sprocket, which requires a ratio of no more than 3.5 to 1 for greater ratios, an idler sprocket may be required to increase wrap angle.

Chapter 7

Ball Bearings

7.1 Introduction

A ball bearing is a type of rolling element bearing that uses balls to maintain the separation between the bearing races. The purpose of a ball bearing is to reduce rotational friction and support radial and axial loads.

It achieves this by using at least two races to contain the balls and transmit the loads through the balls. In most applications, one race is stationary and the other is attached to the rotating assembly (e.g., a hub or shaft). As one of the bearing races rotates it causes the balls to rotate as well. Because the balls are rolling they have a much lower coefficient of friction than if two flat surfaces were sliding against each other.

Ball bearings tend to have lower load capacity for their size than other kinds of rolling element bearings due to the smaller contact area between the balls and races.
However, they can tolerate some misalignment of the inner and outer races.

7.2 Caged

Cages are typically used to secure the balls in a Conrad style ball bearing. In other construction types they may decrease the number of balls depending on the specific cage shape, and thus reduce the load capacity.

Without cages the tangential position is stabilized by sliding of two convex surfaces on each other. With a cage the tangential position is stabilized by a sliding of a convex surface in a matched concave surface, which avoids dents in the balls and has lower friction. Caged roller bearings were invented by John Harrison in the mid 18th century as part of his work on chronographs. Caged bearings were used more frequently during wartime steel shortages for bicycle wheel bearings married to replaceable cups.

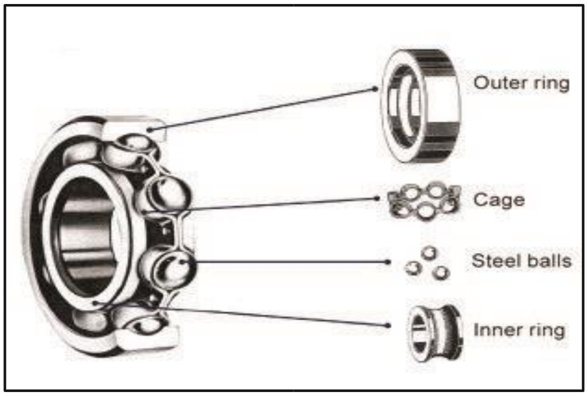

Figure 7.1 Exploded view of ball bearing

7.3 Material used

Chrome steel (AISI 52100 or equivalent) ME STEEL (AISI 52100 or equivalent). This is the standard material used for ball bearing applications where load capacity is the main consideration. The machinability of this steel is excellent, giving smooth, low noise raceway finishes, together with superior life. Chrome steel material is recommended in applications where corrosion is not a factor.

Carbon (c)	Silicon (Si)	Manganese (Mn)	Phosphorous (P)	Sulphur (S)	Chromium (Cr)	Molybdenum (Mo)
0.95- 1.1	0.15- 0.35	Max 0.5	Max 0.25	Max 0.25	1.3 - 1.6	Max 0.6

Table 7.1 Composition of Chrome steel

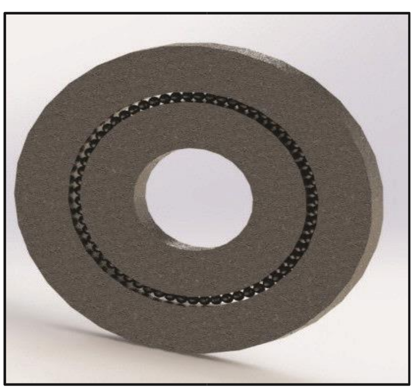

Figure 7.2 Modelled ball bearing

Chapter 8

Bicycle

8.1 Introduction

A bicycle, often called a bike, is a human powered, pedal driven, single track vehicle, having two wheels attached to a frame, one behind the other. A bicycle rider is called a cyclist, or bicyclist.

Bicycles were introduced in the 19th century in Europe and, as of 2003, number more than a billion worldwide, twice as many as automobiles. They are the principal means of transportation in many regions. They also provide a popular form of recreation, and have been adapted for use as children's toys, general fitness, military and police applications, courier services, and bicycle racing.

The basic shape and configuration of a typical upright, or safety bicycle, has changed little since the first chain driven model was developed around 1885. But many details have been improved, especially since the advent of modern materials and computer aided design. These have allowed for a proliferation of specialized designs for many types of cycling.

The bicycle's invention has had an enormous effect on society, both in terms of culture and of advancing modern industrial methods. Several components that eventually played a key role in the development of the automobile were initially invented for use in the bicycle, including ball bearings, pneumatic tires, chain driven sprockets, and tension spoke wheels.

8.2 History

The dandy horse was the first human means of transport to use only two wheels in tandem and was invented by the German Baron . It is regarded as the modern bicycle's forerunner Drais introduced it to the public in Mannheim in summer 1817 and in Paris in 1818. Its rider sat astride a wooden frame supported by two in line wheels and pushed the vehicle along with his/her feet while steering the front wheel.

The first mechanically propelled, two wheeled vehicle may have been built by Kirkpatrick MacMillan, a Scottish blacksmith, in 1839, although the claim is often disputed. In the early 1860s, Frenchmen Pierre Michaux took bicycle design in a new direction by adding a mechanical crank drive with pedals on an enlarged front wheel. Another French inventor named Douglas Grasso had a failed prototype of Pierre Lallement's bicycle several years earlier. Several inventions followed using rear wheel drive, the best known being the rod driven velocipede by Scotsman Thomas McCall in 1869.

The dwarf ordinary addressed some of these faults by reducing the front wheel diameter and setting the seat further back. This, in turn, required gearing effected in a variety of ways to efficiently use pedal power. Having to both pedal and steer via the front wheel remained a problem. J. K. Starley , J. H. Lawson, and Shergold solved this problem by introducing the chain drive (originated by the unsuccessful "bicyclette" of Englishman Henry Lawson), connecting the frame mounted cranks to the rear wheel. These models were known as safety bicycles, dwarf safeties, or upright bicycles for their lower seat height and better weight distribution, although without pneumatic tires the ride of the smaller wheeled bicycle would be much rougher than that of the larger wheeled variety. Starley's 1885 Rover, manufactured in Coventry is usually described as the first recognizably modern bicycle. Soon the seat tube was added, creating the modern bike's double triangle diamond frame.

Further innovations increased comfort and ushered in a second bicycle craze, the 1890s Golden Age of Bicycles. In 1888, Scotsman John Boyd Dunlop introduced the first practical pneumatic tire, which soon became universal. Soon after, the rear freewheel was developed, enabling the rider to coast. This refinement led to the 1890s invention of coaster brakes. Hand operated Bowden cable pull brakes were also developed during these years, but were only slowly adopted by casual riders. By the turn of the century, cycling clubs flourished on both sides of the Atlantic, and touring and racing became widely popular.

Bicycles and horse buggies were the two mainstays of private transportation just prior to the automobile, and the grading of smooth roads in the late 19th century was stimulated by the widespread advertising, production, and use of these devices.

8.3 Conclusion and future prospects

In the last 10 years of the 19th century at least one third of all the new patent applications sent to the U.S. Patent Office were bicycle related. The past 20th century technical and material design for bicycles at times increased greater than automobile design. Now in the 21st century even the said “low class” (inexpensive) bicycles are pushing boundaries of lightweight, efficient, functional, and high performance needs of the cyclist. In conclusion, we could say that bicycles have a big future due to their increasing popularity of use thus material selection and design will lead that future in terms of technology. Low environmental impacts have been added incentive for present popular use in contrast to the automobiles for commuting. But as always, popular use is driven by utility of cheap efficient exercise and transportation

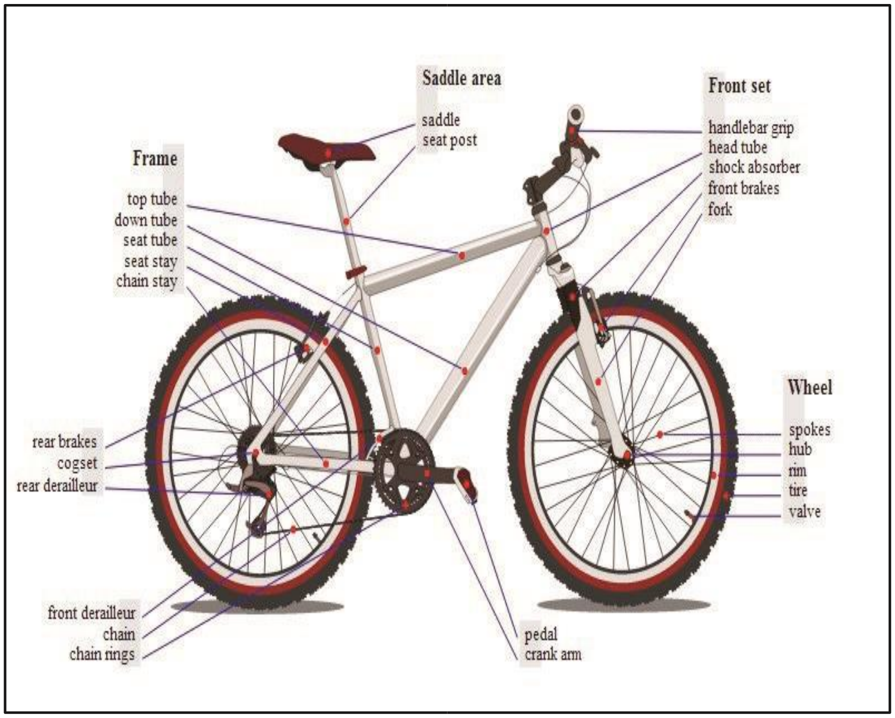

Figure 8.1 Cycle parts

Figure 8.2 Modelled cycle

8.4 Advantages of Riding a Bicycle

1. It is an environmentally friendly mode of transport.
2. You save money on fuel (Gas, Petrol, Diesel or whatever you call it in your country) by riding a bicycle.
3. A bicycle requires comparably less maintenance.
4. Riding a bicycle is good for your health. You develop a strong heart and muscular limbs.
5. You can weave in and out of traffic.
6. Riding a bicycle is a quicker way of getting around the city. I have found that inside city, while driving automobiles, you can hardly go above 35 Km/hr. And many times you are forced to move at a crawl.
7. There are no parking problems. And you do not have to pay a toll for parking in special spots.
8. Riding a bicycle to work every day, you do not have to set aside time for exercise as this in itself is an exercise. Thus the time saved can be used for other tasks.
9. The slow pace of travel helps you be receptive of the sights around you, which you might in all probably have missed while riding an automobile.

Chapter 9

Materials Description

9.1 EN 16

EN16 also known as 605m36 comes as rolled (no heat treated) or hardened and tempered to T condition. EN16T is a high tensile steel with good mechanical properties and has freedom from temper brittleness idea for bolts, nuts, shafts and axles. Readily machinable. EN16 as rolled (un heat treated) is also available, usually in larger diameters. EN16 is an alternative alloy steel grade to other chromium and nickel chromium high tensile steel specifications, offering excellent ductility, freedom from temper brittleness and is readily machinable in the supply condition.

The original 'EN' or 'Emergency Number' material designation was developed during the years of WW2 to aid the standardisation of steel reference specification and production of components produced from materials. The EN reference has continued to be used from that time many attempts over the years have been made to update and circulate a new standard, but the original EN designation tends to remain in the workplace. The second most common material designation used in the UK is probably the BS970 standard although officially this has been superseded by another european standard, confusingly also named the 'BS EN' number. The BS970 standard however was designed to clearly detail the carbon content and the specific type of steel via the numbers and letter given to the material. (as shown below)

Figure 9.1 Standards **9.1.1 Steel Type**

This three digit number indicates the type of steel
000 to 199 Carbon manganese steel, number shows the manganese content. (x100)

200 to 240 Free cutting steel, the 2nd and 3rd digit represents the sulphur content. (x100)

250 to 250   Silicon manganese steel.

300 to 499   Stainless steels and steels resistant to heat.

500 to 999   Reserved for alloyed steels.

9.1.2 Letter

The single letter will be one of four designations, A, H, M or S

A   The steel is supplied to a chemical composition as attained from a chemical batch.

H   The steel specification is 'hardenable'.

M   The material is produced to certain mechanical properties.

S   The steel is stainless in specification.

9.1.3 Carbon content

The last two numbers represent the average material carbon content. (x100). Sometimes a further letter can be added to the designation when a certain heat treatment condition has been applied.

9.1.4 Process

Annealing

Heat slowly to 640 660°C. Cool in air

Hardening

This steel grade is commonly supplied ready heat treated. If further heat treatment is required annealed EN16 should be heated slowly to 840 870°C and after adequate soaking at this temperature quench in oil. Temper as soon as tools reach room temperature.

Tempering

Heat carefully to a suitable temperature selected by reference to a tempering chart or table. Soak at the temperature for 2 hours per 25mm of ruling section, then allow to cool in air. Tempering between 250 375°C is not advised as tempering within this range will seriously reduce the impact value.

Heat treatment

Heat treatment temperatures, including rate of heating, cooling and soaking times will vary due to factors such as the shape and size of each steel component. Other considerations during the heat treatment process include the type of furnace, quenching medium and work piece transfer facilities. Please consult your heat treatment provider for full guidance on heat treatment of alloy steel.

Heat treatment	Tensile strength N/mm^2	Yield strength N/mm^2	Impact strength	Hardness HRC	Size mm
R	700 – 850	525	40	201-225	≤150
S	775 – 925	585	40	223 -277	≤100
T	850-1000	680	35	248-302	≤63

Table 9.1 Mechanical properties

Specifications	Chemical composition in percentage					
	C	Si	Mn	Mo	S	P
EN 16	0.3-0.4	0.10-0.35	1.3-1.8	0.2-0.35	0.05	0.05

Table 9.2 Chemical composition of EN 16

9.1.5 Applications

Commonly used for general engineering applications EN16T is suitable for applications such as high tensile shafts, bolts and nuts, gears, pinions spindles.

9.2 EN 9

EN9, also known as 070m55, available in diameters, flats, squares and plates with a carbon content 0.50/0.60 this is a medium carbon steel which can develop a tensile strength of 700N/mm 45tsi. In the normalised condition EN9 can be used for gears, sprockets and cams. EN9 is a medium carbon steel grade commonly supplied in the as rolled condition. It can be flame or induction hardened to produce a high surface hardness with excellent wear resistance for a carbon steel grade. EN9 bar is available in full lengths or can be cut to your requirements. EN9 flame cut steel plates can be supplied cut to your required sizes and normalized.

Specification	Chemical composition in percentage					
	C	Si	Mn	Mo	S	P
EN 9	0.5-0.6	0.05-0.35	0.5-0.8	0.2-0.35	0.06	0.06

Table 9.3 Chemical composition of EN 9

9.2.1 Process

Do not forge below 850°C. After forging cool slowly, preferably in a furnace. Annealing Heat the steel slowly to 680 710°C, soak well. Cool slowly in the furnace. Hardening Heat slowly to 820 840°C and allow it to be heated through. Quench in oil, brine or water. Tempering Temper the EN9 steel component immediately after quenching whilst still hand warm. Re heat to the tempering temperature then soak for one hour per 25 millimetre of total thickness (2 hours minimum) Cool in air. For most applications tempering of EN9 will be between 550 660°C Welding .Heat Treatment Heat treatment temperatures, including rate of heating, cooling and soaking times will vary due to factors such as the shape and size of each EN9 steel component. Other considerations during the heat treatment process include the type shape and size of each EN9 steel component. Other considerations during the heat treatment process include the type of furnace, quenching medium and work piece transfer facilities. Please consult your heat treatment provider for full guidance on heat treatment of EN9 carbon steel.

9.2.2 Applications

EN9 is used commonly for many general engineering applications. Typical applications includes, shafts, axes, knives, bushes, crankshafts, screws, sickles, wood working drills and hammers. Forging Preheat the component carefully, then raise the temperature to 1100°C for forging.

9.3 High carbon steel

Carbon steel is steel in which the main interstitial alloying constituent is carbon in the range of 1.5–1.6%. The American Iron and Steel Institute (AISI) defines carbon steel as the following steel is considered to be carbon steel when no minimum content is specified or required. When the maximum content specified for any of the following elements does not exceed the percentages noted.

As the carbon percentage content rises, steel has the ability to become harder and stronger through heat treating however it becomes less ductile.

Regardless of the heat treatment, a higher carbon content reduces weld ability. In carbon steels, the higher carbon content lowers the melting point.

9.3.1 Types

Carbon steel is broken down into four classes based on carbon content

9.3.1.1 Mild and low carbon steel

Mild steel, also known as plain carbon steel, is the most common form of steel.

Because its price is relatively low while it provides material properties that are acceptable for many applications, more so than iron. Low carbon steel contains approximately 0.05– 0.3% carbon making it malleable and ductile. Mild steel has a relatively low tensile strength, but it is cheap and malleable surface hardness can be increased through carbonizing.

9.3.1.2 Higher carbon steels

Carbon steels which can successfully undergo heat treatment have carbon content in the range of 0.30–1.70% by weight. Trace impurities of various other elements can have a significant effect on the quality of the resulting steel. Trace amounts of sulphur in particular make the steel red short, that is, brittle and crumbly at working temperatures. Low alloy carbon steel, such as A36 grade, contains about 0.05% sulphur and melts around 1,426–1,538 °C (2,599–2,800 °F). Manganese is often added to improve the harden ability of low carbon steels. These additions turn the material into low alloy steel by some definitions, but AISI's definition of carbon steel allows up to 1.65% manganese by weight.

9.3.2 Process

Hardening

Heat uniformly to 830 / 860 °C until heated through. Quench in oil or water. Can also be induction or flame hardened.

Tempering

Heat uniformly and thoroughly at the selected tempering temperatures, between 550°C to 660°C and hold at heat for one hour per inch of total thickness.

Chapter 10

Working

The energy is stored and gained back as shown in figure

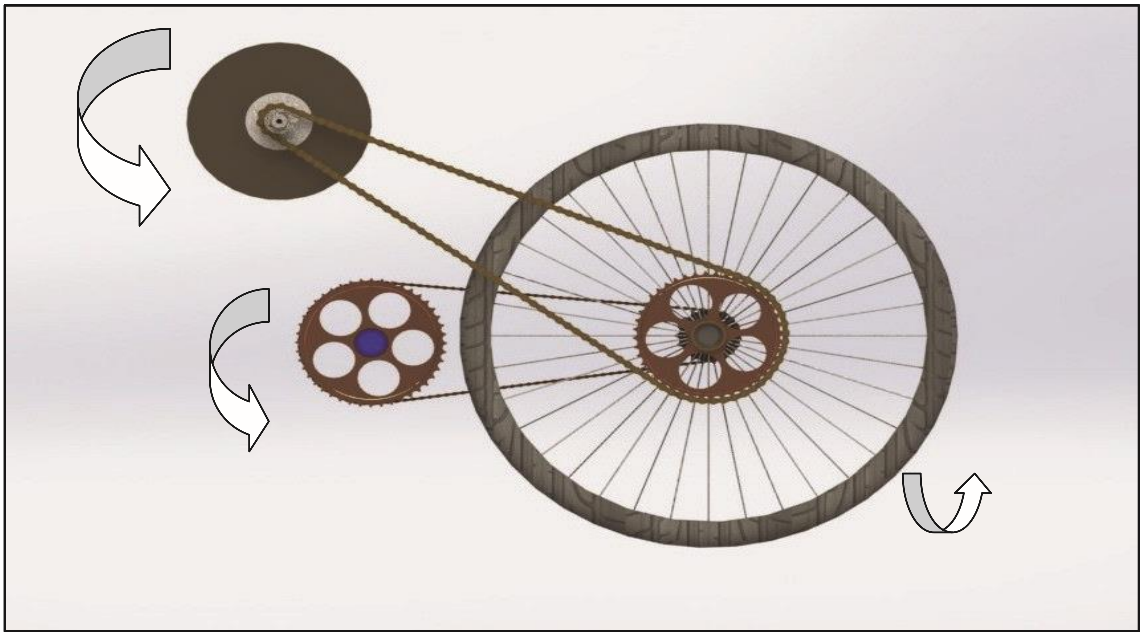

Figure 10.1 Energy Stored

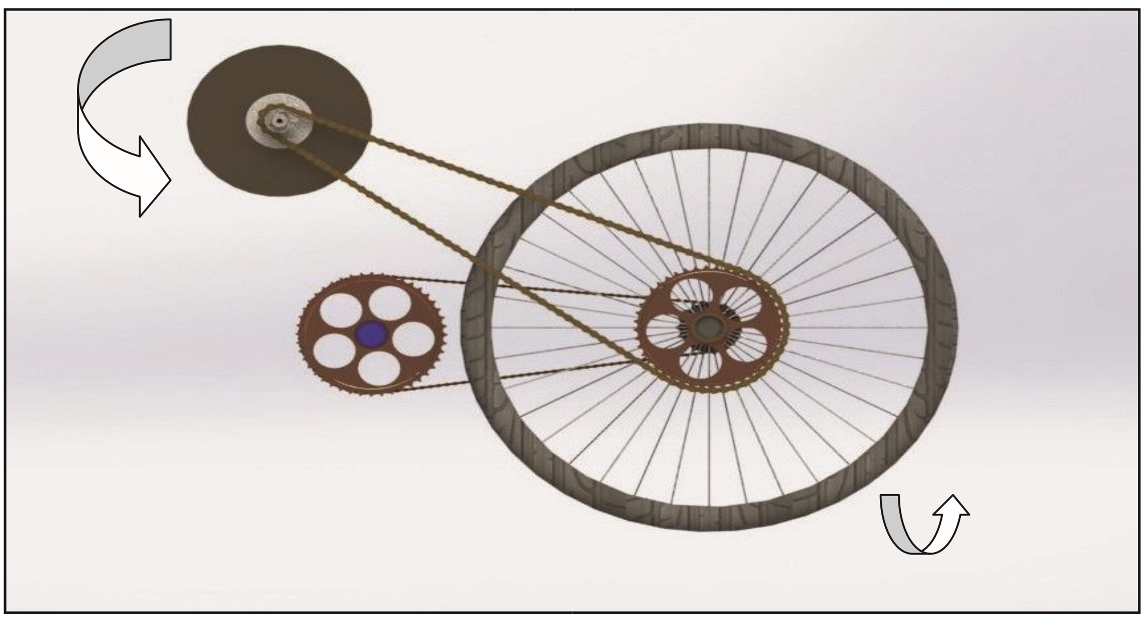

Figure 10.2 Energy regained

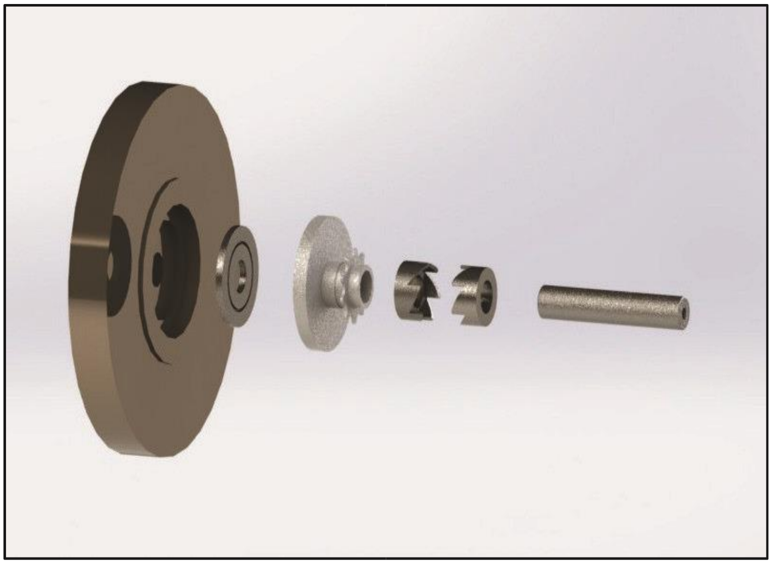

Figure 10.3 Exploded View

Figure 10.4 View 1

Figure 10.5 View 2

Chapter 12

Conclusions and Future Implementation

The following conclusions can be drawn from this project

1. Reduced energy consumption.
2. Reduced running costs.
3. Decrease in wear and tear of tyres and brake linings.
4. The flywheel based KERS is the more commonly used form.
5. Its efficiency is high compared to normal cycles.
6. Lighter
7. Cheaper
8. It provides a more stable output
9. As the technology is further developed, we can expect KERS to be implemented in automobiles in the near future .

Future implementation

1. Energy storage is possible in the form of electrical energy by coupling it with the dynamo. This energy can be utilized to power up other auxiliary units in the vehicle.
2. The energy stored can also be used as braking the vehicles, acts as an emergency or auxiliary source for braking.

References

[1] On the influence of the clutch disks pre damper parameters – Vinicius Gabriel Segala Simionatto, Hugo Heidy

[2] Springer handbook of mechanical engineers – Karl Heinrich Grote, Erik k. Antonsson

[3] Optimization of shape and design parameters of the rigid clutch disc – Oday I. Abdullah, Germany

[4] VDI guidelines 2241, Part 1 – Dusseldorf

[5] SAE paper – Friction clutches – Sharipov and Dmitriev

[6] The Flywheel Energy Storage System (FESS) Jake Amoroso, New York

[7] Machine Design II – Prof. K. Gopinath and Prof. M.M. Mayuram

[8] High Speed flywheel design – Tobias Kamf, Uppsala Universitet

Websites

[9] http // www.msn.com

[10] http //www.hotbot.com

[11] http //www.steelexpress.com

[12] http //www.hollowbar.co.za

[13] http //www.brighthubengineering.com

[14] http //www.britishv8.org